SCIENTIFIC JUSTIFICATION

Introduction: The Search for Dark Companions

Quiescent compact objects—neutron stars (NSs) and stellar-mass black holes (BHs)—are expected to be abundant in the Milky Way, yet they remain observationally elusive when not accreting. Identifying these "dark" companions in non-interacting binaries is critical for constraining the compact-object mass function, particularly in the theorized "lower mass gap" (~ 2.5–$5\,M_{\odot}$). Radial-velocity (RV) surveys offer a purely gravitational discovery channel, but candidate systems are frequently compromised by stellar blends and wavelength-dependent systematics in wide-field fiber pipelines.

The Candidate: Gaia DR3 3802130935635096832

A systematic search of DESI DR1 Milky Way Survey multi-epoch RVs identified Gaia DR3 3802130935635096832 as a high-amplitude RV variable with minimal multi-wavelength signatures of a luminous companion. The target is faint ($G = 17.273$) and M-dwarf like. DESI provides four RV epochs spanning 38.9 days with a catalog RV span $\Delta\mathrm{RV} \approx 146$ km s^{-1}. A constant-RV model is rejected at $\Delta\chi^2 \approx 2.7 \times 10^4$ (DESI-only).

Gaia DR3 astrometry independently flags this object as astrometrically complex: RUWE = 1.954 and astrometric excess noise $\epsilon_{\mathrm{AEN}} = 0.90$ mas at 16.5σ significance (verified directly from `gaiadr3.gaia_source`). These metrics indicate a poor single-source fit consistent with unresolved duplicity and/or orbital motion. However, Gaia also resolves a nearby neighbor (see below), requiring blend-aware interpretation.

The Forensic Complication: A Resolved Blend, and Why the RV Still Matters

Gaia DR3 resolves a neighbor at $\rho \simeq 0.69''$ with $\Delta G \simeq 2.21$ mag, inside the $1.5''$ DESI fiber. This is a classic failure mode for "dark companion" candidates: blending can corrupt fiber-based RV extraction.

We therefore performed a forensic re-analysis using DESI per-exposure, per-camera spectra (cframe products), isolating wavelength regions to identify stable RV estimators. The critical result is:

- The DESI Z-arm **full-band** RV is unstable between two same-night exposures separated by 15 minutes (a 34 km s^{-1} discrepancy), indicating sky-region calibration sensitivity.
- Restricting to the Ca II triplet window (8500–9000 Å) yields **stable** same-night RVs (2.8 km s^{-1} difference; $\sim$12$\times$ improvement) and recovers a large RV swing.
- The "trusted window" RV curve (Ca II triplet only) yields $\Delta\mathrm{RV} \approx 151$ km s^{-1} (from -85.6 to $+65.6$ km s^{-1}), consistent with the original high-amplitude variability, while showing that the DESI catalog RVs for the same-night pair were biased low by ~ 25 km s^{-1} due to the unstable sky-dominated red end (9000–9800 Å).

Thus, the blend is real, but the high-amplitude RV variability survives a conservative, exposure-level truth filter that removes the dominant instrumental pathology. The remaining uncertainty is physical: which component is moving, and what companion mass follows once the blend is resolved.

Goal: Spatially Resolved Spectroscopic Confirmation

Fiber spectroscopy cannot definitively separate two sources at $0.69''$. We request spatially resolved slit spectroscopy to:

1. **Resolve the blend:** Obtain slit spectra with a position angle that separates the primary and neighbor along the slit (or minimizes neighbor contamination), enabling independent extraction.
2. **Confirm the RV amplitude on a clean spectrum:** Measure a 100 km s^{-1} RV change with uncontaminated extraction, directly testing the compact-companion hypothesis.
3. **Classify the system:** Determine whether the system is SB1 (dark companion) or SB2 (luminous binary), and obtain stellar parameters to improve the primary mass estimate.

This is well-matched to the Fast Turnaround mandate: a small time investment to decisively validate (or reject) a rare high-amplitude, quiescent compact-companion candidate that has already survived strong public-data truth filtering.

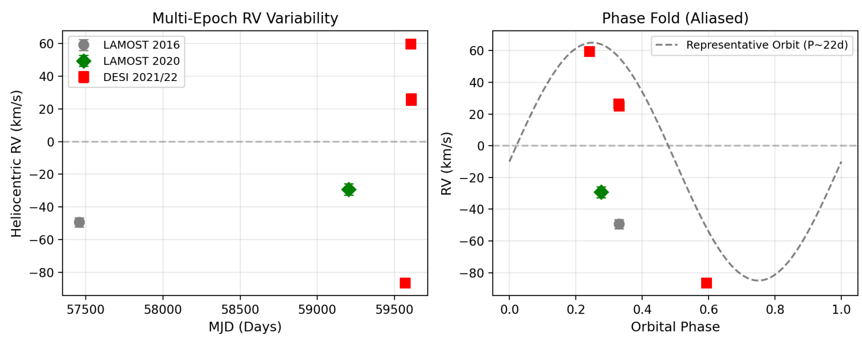

Figure 1: *Left:* DESI RV time series showing the large amplitude variability. *Right:* Conservative "trusted-window" (Ca II triplet) RV measurements from per-exposure DESI spectra recover a ~ 151 km s^{-1} swing while suppressing the known Z-arm sky-region instability. Sparse cadence leaves the period aliased; Gemini epochs provide decisive anchor points.

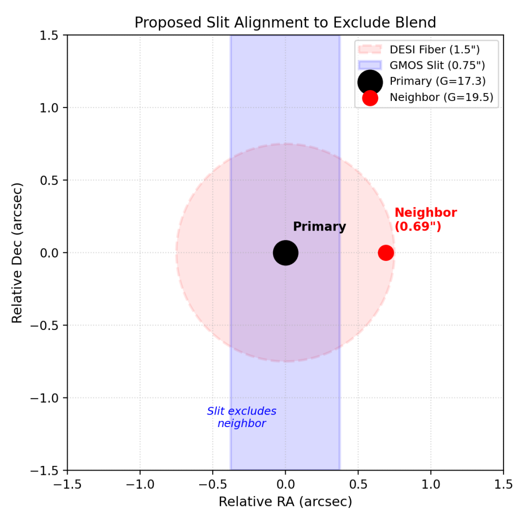

Figure 2: Legacy Survey imaging / Gaia-resolved neighbor at $\rho \simeq 0.69''$ (inside DESI fiber). Gemini long-slit spectroscopy with an appropriate PA can separate the components and eliminate blend ambiguity.

TECHNICAL CASE

Instrument Configuration

We request **GMOS-N** in long-slit spectroscopy mode.

- **Grating:** R831 ($R \sim 2000$–4000), sufficient for RV precision of ~ 5–10 km s^{-1} at SNR ~ 15–20 in the red.
- **Filter:** OG515 (blocks second order).
- **Central wavelength:** 850 nm, to cover the Ca II triplet (trusted RV window) and nearby M-dwarf molecular structure.
- **Slit width:** $0.75''$ (balance of throughput and resolution).
- **Slit PA:** We request a PA aligned to maximize separation of the two sources along the slit (or place the neighbor off-axis), using the Gaia-measured separation vector.

Exposure Times and RV Precision

The target has $G = 17.27$ with red magnitude approximately $r \sim 16.5$ and $z \sim 15.5$. The science requires confirming large RV excursions (tens to 100 km s^{-1}), not sub-km s^{-1} precision. With GMOS-N R831, a single 45-minute exposure split into 3×900 s yields SNR ~ 15–20 per resolution element in the Ca II triplet region, sufficient for ~ 5–10 km s^{-1} RV precision.

Scheduling and Cadence

We request 3 epochs separated by ~ 3–10 days. The goal is to obtain new anchor points that (i) confirm the RV swing in clean slit extraction and (ii) distinguish SB1 vs SB2. Because the DESI period remains aliased, moderate spacing is acceptable; any two widely separated velocities at the ~ 50 km s^{-1} level are decisive.

Conditions (Queue Filler Strategy)

We request relaxed constraints to maximize scheduling efficiency: CC70/80, IQ85, and SBAny. The slit orientation and extraction will mitigate blend effects, and the amplitude to be confirmed is large. The program is therefore suitable as an efficient queue filler in suboptimal weather bands or bright time.

Total Time Request

3 epochs $\times$ (45 min science + 15 min overhead) = **3.0 hours**.

DUPLICATE OBSERVATIONS

A search of the Gemini Observatory Archive (GOA) revealed no duplicate observations of this target (Gaia DR3 3802130935635096832) with GMOS-N or comparable long-slit spectroscopy suitable for resolving the $0.69''$ blend. Existing data are limited to wide-field survey fibers (DESI, LAMOST), motivating this request.

ITC ATTACHMENTS